

SEAFLOOR EARTHQUAKE MEASUREMENT SYSTEM  
Quarterly Report

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Project Description

The objectives of the SEMS project are: (1) to design, develop, install, and interrogate sea-bottom seismic stations and, (2), to analyze the seafloor motion records to provide a seismic characterization of offshore oil and gas leasing regions. The principal areas of interest are offshore of Southern California, in the Southern Bering Sea, and near the Aleutian Islands. Plans call for the FY 1989 installation of the high-sensitivity California Offshore Seismic Array (COSA) with units off of Long Beach and Point Arguello. Given that sufficient government and industry funding can be obtained, the project will eventually emplace and monitor multiple SEMS units offshore Alaska.

Progress

During this quarter various analytical, and laboratory tasks were undertaken. The major activities during this quarter involved (1) the extensive post-mortem testing of the SEMS unit recovered offshore Long Beach, (2) the initiation of an electronics design effort for an improved SEMS unit, and (3) a comparison between earthquake data recorded by SEMS, on-shore seismic stations, and the Shell Eureka offshore platform.

LABORATORY WORK: SEMS POST-MORTEM TESTS

During this quarter, extensive post-mortem tests were performed on the SEMS unit recovered from offshore Long Beach, CA. The objectives of the tests were; isolate subsections of SEMS which have faulty operation, determine the source of electronic noise which was masking out seismic events, determine the source of false triggering, and to outline the work required to improve the unit.

The two major deficiencies with the Long Beach SEMS unit were found to be: (1) lack of sensitivity to seismic motions and (2) excessive power consumption. The lack of sensitivity is the primary cause for the SEMS failure to record some earthquakes and the excessive power consumption resulted in a shortened

field life. The post-mortem tests revealed the exact causes of these deficiencies and enabled a plan for greatly improving the SEMS performance.

The SEMS lack of seismic sensitivity stems from both software and hardware limitations of the SEMS unit. The SEMS sensitivity is greatly reduced as a result of its software earthquake detection algorithm. The detection algorithm uses only the output of the vertical accelerometer to measure seismic activity. Data obtained from SEMS, however, strongly suggest (see below) that the vertical seafloor motions are greatly reduced relative to corresponding on-land vertical motions. This aspect of seafloor seismic response served to limit the SEMS performance.

The second cause for SEMS lack of sensitivity is the presence of significant electronic noise within the SEMS unit itself. The noise is due to the electronic circuitry which processes the analog accelerometer signals. The SEMS Analog Data Acquisition Board (ADAB) provides inadequate filtering of noise. Additionally, the power supplies for the ADAB introduce significant noise. Another noise source is the coupling of digital signals (e.g. the microprocessor clock) into the ADAB through ground loops. As a result of the SEMS post-mortem tests, methods have been found to greatly reduce the electronic noise, and thereby significantly improve the SEMS sensitivity.

#### ANALYTICAL WORK: DEVELOPMENT OF SEMS III

The present SEMS system is a well conceived instrumentation package which is novel in its capabilities and applications. Despite some past problems with the operating details of the system, the recovered hardware is functional and can be recycled for re-deployment. An electronics modification has been proposed to greatly improve the performance of SEMS. The improved SEMS, named SEMS III, will have the following advantages:

- greatly improved sensitivity to earthquakes
- extremely precise measurements
- improved remote diagnostics and calibration capabilities
- a 5-7 year field life.

In order to obtain this improved performance, various aspects of the SEMS require redesign. A state-of-the-art ADAB has been designed that offers extremely precise noise-free recording of both very small local earthquakes (typical of Southern California) and very large earthquakes (as found offshore Alaska). To further improve the sensitivity of the system, new power supplies are being constructed and ground isolation incorporated.

A unique feature of SEMS III is enhanced sensitivity through the use of a novel earthquake detection algorithm based on horizontal accelerometer signals. The horizontal-based algorithm will be particularly robust since it will buffer large amounts of data in order to capture the vertical p-wave. The vertical p-wave can occur many seconds prior to the horizontal shear motions.

The new detection algorithm will be quite insensitive to noise phenomena which can cause false triggering. There are three types of noise phenomena which

SEMS needs to discriminate against: (1) low frequency noise (less than 2 Hz) which results either from electronic drift or tele-seismic events; (2) High frequency noise or spikes (greater than 10 Hz) which result from digital electronic sources or local marine-life interactions; (3) background electronic and seismic noise in the frequency range of interest (2-10 Hz). An optimal signal processing algorithm which uses horizontal motions and implements real-time digital filtering to discriminate against these noise phenomena is currently under investigation.

The intended SEMS sites offshore California are indicated in Figure 1. The first deployment site is offshore Long Beach (October 1988) near Shell platforms, while the second deployment site is offshore Point Arguello (Spring 1989) near Union Oil of California platforms. Also indicated in Figure 1 is the locations and magnitudes of detected earthquakes over a 50 year period. SEMS III calculated sensitivity to earthquakes is indicated by circles around the SEMS site. It is seen from Figure 1 that SEMS will be capable of accurately measuring all earthquakes of magnitude 4.0 or greater within a 40 km radius of a SEMS site. Based on the seismic history near the SEMS sites, there is a high probability that the deployed SEMS units will record several of these smaller earthquakes during their lifetime. An additional feature of the offshore California SEMS units is that they form a seismic array for moderate-to-large earthquakes. Specifically, the two units will be capable of simultaneously recording earthquakes of magnitude 4.7 or larger in the Santa Barbara Channel. Earthquakes of magnitude 5.0 or greater in the Los Angeles Basin or on portions of the San Andreas Fault will also be simultaneously recorded by the two SEMS units. The large amount of data collected by SEMS III will provide invaluable offshore seismic information.

#### ANALYTICAL WORK: ANALYSIS OF OFFSHORE SEISMIC DATA

During this quarter, an extensive analysis was performed on recorded offshore earthquake data. For the July 8, 1986 North Palm Springs Earthquake, a comparison was made between SEMS measurements, Shell's Eureka Platform mudline acceleration measurements, and land-based measurements [1,2]. This analysis has led to some extremely interesting conclusions regarding offshore ground and structural seismic response. At this time, however, details of the analysis and results can not be revealed due to the proprietary nature of the Shell data. The general conclusions, however, are:

- The vertical component of acceleration observed at both the SEMS' site (i.e. free-field seafloor motion) and on the platform legs is significantly different than the corresponding vertical components of acceleration observed on-shore. A statistical analysis has shown that the offshore peak vertical accelerations are an order of magnitude weaker than the corresponding on-shore measurements. This phenomena is illustrated in Figure 2 where SEMS data and land-based data are compared.
- It appears that the peak horizontal components of acceleration observed at the SEMS site and by the platform legs are comparable to the corresponding on-shore measurements. Additional earthquake data obtained from future earthquakes will be required to either confirm this observation or point out the subtle differences between on-shore and offshore horizontal accelerations. Additional offshore earthquake data will also

serve to further verify the reduced offshore vertical seismic motions.

- While both SEMS and on-shore records have fairly broadband response spectra, the platform data indicates a fairly narrow-band response spectra. This difference is most likely attributed to the soil/structure interaction. A more sophisticated analysis will be required to quantify this effect.

The above conclusions have important implications for the design of offshore structures. It is clear that earthquake data obtained offshore will greatly aid in the design and regulation of offshore structures.

#### NEXT QUARTER ACTIVITIES

Proposed activities for next quarter include:

1. Redesign and implement new power supplies and ground system for Long Beach SEMS.
2. Generate schematic diagrams and test circuits for new ADAB.
3. Continue evaluation of new probe emplacement procedures.
4. Complete evaluation of advanced SEMS trigger algorithm.
5. Begin SEMS software modifications.
6. Meet with DOE and MMS to discuss present and future funding status.
7. Meet with Shell Oil regarding future participation in SEMS program.

#### REFERENCES

- [1] Huang, M.J., et al, "CSIMP strong-motion records from the Palm Springs, California earthquake of 8 July 1986," California Dept. Conserv., Div. Mines and Geol., Report OSMS 86-05, 1986.
- [2] Porcella, R.L., et al, "Strong motion data from the July 8, 1986 North Palm Springs earthquake and aftershocks," U.S.G.S. Open-File report 87-155, 1987.

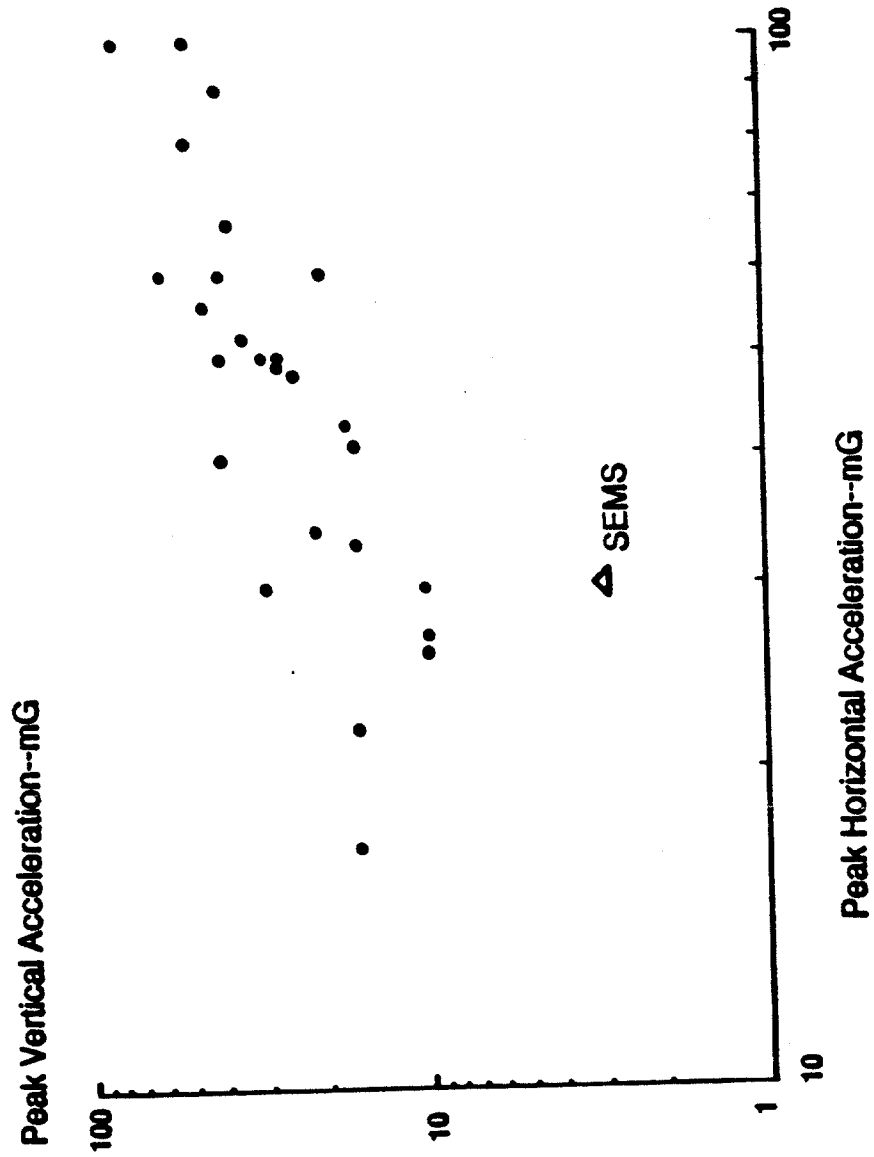


Figure 2. Comparison of land-based acceleration measurements (dots) with SEMS acceleration measurement (triangle) resulting from 8 July 1986 North Palm Springs Earthquake.



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